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AIR DEFENSE: A COMPUTER GAME FOR RESEARCH IN HUMAN PERFORMANCE.(U)
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AIR DEFENSE: A COMPUTER GAME FOR RESEARCH IN HUMAN PERFORMANCE

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NAVY PERSONNEL RESEARCH
AND
DEVELOPMENT CENTER
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AIR DEFENSE: A COMPUTER GAME FOR RESEARCH IN HUMAN PERFORMANCE

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A laboratory simulation system was developed for research on human performance in anti-air warfare (AAW) threat analysis. Major elements of the threat analysis problem were embedded in an interactive air defense game controlled by a desktop micro-computer. The problem for the player is to decide when to launch "missiles" at hostile targets that approach at different speeds, and the task load is manipulated by varying the number of targets and their arrival rate. The specification of a mathematically ideal

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) information processor provides a standard of optimal performance. Feedback is given to the player after each engagement, and performance data are automatically stored for subsequent analysis.

Navy enlisted men served in a demonstration experiment that confirmed the feasibility of the system. Approximately 3 hours of practice produced proficient levels of performance. The course of skill acquisition was largely insensitive to training manipulations. Effects of task load were evidenced by a decline in performance as the number of targets and the pace of operations were increased. Performance was also impaired by the introduction of a concurrent auditory monitoring task. Test subjects found the game challenging and sustained their attention to the task for extended periods.

FOREWORD

This research and development was conducted in support of Project ZF57-525-001-022-03.06 (Improving Human-Computer Interaction for Command and Control Systems) under the sponsorship of the Naval Sea Systems Command. The objective of this project is to enhance the effectiveness of command and control systems through improved design of the human-computer interface. In particular, the project is designed to examine the impact of information overload on threat analysis performance in anti-air warfare and to recommend procedures for reducing the impact of such overload on operational readiness.

This report documents the initial effort toward quantifying limits in human information processing that are associated with critical command and control operations. The research vehicle reported here will provide the basis for subsequent investigations of human decision and information processing behavior.

Appreciation is expressed to EMC Jones of the Naval Training Center, San Diego, and to Dr. Carl Englund of the Naval Health Research Center, San Diego, for their assistance in providing research subjects.

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SUMMARY

Problem

The analysis of threat is a critical function in many combat systems, especially under the conditions of high information load that typify anti-air warfare (AAW) operations. To reduce the effect of information overload on AAW operator performance, it is necessary to understand more precisely the relationship between task load and decision performance. Proper investigation of this relationship requires the development of a research vehicle that embodies major features of the AAW threat analysis problem and permits detailed quantitative measurement of human performance.

Objective

The objective of this effort was to develop and test a system for investigating human performance in the conduct of AAW threat analysis. The system had to be flexible, be portable, require minimal training, induce a high motivation to perform, and provide detailed measurement of human performance.

Approach

A simulation of the AAW threat analysis problem was developed and embedded in an interactive "air defense game" driven by a Tektronix 4051 microcomputer. The game simulated hostile air targets approaching the player's ship at one of three speeds. The entire scenario was displayed on the computer's CRT screen. Task difficulty was manipulated under computer control by varying the number of targets and their arrival times. The player defended the ship by launching "missiles" at the incoming targets. The ship's detection range exceeded the range of its missiles, however, so that a launch-time decision was necessary for each target. The goal for the player was to kill all threats at maximum range, but missiles launched too early would fall short of the target and be ineffective.

Following each engagement, the computer program gave performance feedback to the player and stored all relevant data for subsequent review by the experimenter. A data analysis program was developed to provide details of player performance.

Seventeen Navy enlisted men served in an initial experiment to evaluate the system's utility for human performance research. Task variables were the number of targets in each engagement, the pace or tempo of operations, and target speed. The effects of two different training sequences and of a concurrent auditory monitoring task were also investigated.

Findings

1. The feasibility of the software concept and its implementation were confirmed by the preliminary experiment.

2. On-line extraction of performance data permitted researchers to compare the performance of the players with that of a mathematically ideal information processor.

3. Test subjects became proficient after about 3 hours of practice. Training manipulations had little effect on the course of skill acquisition.

4. The effects of task load were evidenced by a decline in performance as the number of targets and the pace of operations were increased. Performance was also impaired by the introduction of a concurrent auditory monitoring task.

5. The air defense game was challenging and induced a high level of motivation. Test subjects sustained their attention to the task for 3 to 4 hours at a sitting.

Conclusions

The air defense game offers a rich analogue of AAW threat operations. It is readily learned, motivating to perform, and provides an effective vehicle for human performance research.

Recommendations

1. The air defense game should be exploited as a tool in future research on the threat analysis problem.

2. The air defense game should be used to determine limitations in human information processing and to find out how threat analysis strategies change as a function of task load.

3. Performance in the air defense game should be used as a dependent measure in other military research applications (e.g., the effect of sleep loss or extended effort).

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INTRODUCTION

Problem

The analysis of threat is a critical function in many combat systems, especially under the conditions of high information load that typify anti-air warfare (AAW) operations. In order to reduce the effect of information overload on AAW operator performance, it is necessary to understand more precisely the relationship between task load and decision performance. Proper investigation of this relationship requires the development of a research vehicle that embodies major features of the AAW threat analysis problem and permits detailed quantitative measurement of human performance.

Objective

The objective of this work was to develop and test a system for investigating human performance that would:

- Exercise the complex cognitive processes encountered in AAW threat analysis operations.
- Require minimal training.
- Make minimal psychomotor demands.
- Enable detailed performance measurements.
- Have a military character and be inherently motivating to perform.
- Use a single stand-alone microcomputer.
- Be flexible enough to enable the use of varied scenarios.
- Permit ready evaluation of its operation.

Background

As the naval tactical environment becomes more complex and fast-paced, the need for timely and effective decisions imposes an increasingly heavy burden on command. Human performance and the design of the human-computer interface become critical. Thus, it is imperative that combat systems be designed to minimize potential performance deficits under conditions of heavy information load. Proper guidelines for design should include quantitative human performance data, as has been emphasized by representatives of NAVELEX, fleet C^2 sites, and the Chief of Naval Operations (Command, Control, and Communications Programs Office (OP-94)). The Navy Personnel Research and Development Center (NAVPERSRANDCEN) has an ongoing research effort that seeks to quantify human performance limits in dealing with AAW threats.

The problem of information overload is especially acute at the level of the individual ship, where the Combat Direction Center staff must integrate data from several sources to detect, classify, and monitor contacts. Staff personnel must attend concurrently to multiple contacts and make accurate and timely decisions under stress (Combat Direction Systems Department Organizational Manual, USS AMERICA (CV 66), 1978; Cullison, 1979; Halnon, 1979).

The analysis of threat in tactical operations is largely a covert, cognitive activity about which little is known. In general terms, decision makers must recognize contacts as potential threats, set priorities, and initiate appropriate actions to neutralize contacts determined to be hostile. A Ship Weapons Coordinator (SWC), for example, must respond to messages and alerts from the staff, monitor the status of potential threats, assign the appropriate weapons, and carry out directives from his superiors. This sequence works reasonably well in routine situations, but problems occur when track loads become heavy, as they often do in AAW operations. Here the rate of information flow increases dramatically and performance begins to degrade. The SWC's job is especially vulnerable to information overload.

A recurring problem in the study of information overload has been the selection of a measure of cognitive performance that is sensitive to variations in task load. The more successful studies, such as those by North and Gopher (1976) and Wickens and Gopher (1977), have addressed the aircraft environment. Typically, a compensatory tracking task has been used to simulate the psychomotor demands of flying. The tracking task was performed in conjunction with other tasks, such as map reading, and tracking error was then taken as an indicator of mental workload. Harris, North, and Owens (1978) have described an experiment controller system that employs this paradigm. The specifics of this dual-task paradigm cannot be applied directly to AAW, however, because AAW problems place little or no reliance on psychomotor skills like tracking. Instead, AAW subsystems require sustained attention to complex information processing tasks in which threat analysis has high priority. Therefore, at the start of this effort, a research tool was needed that would incorporate the cognitive features of AAW threat analysis, provide close experimental control of task events, and yield detailed quantitative measurements of human performance.

AIR DEFENSE GAME

A laboratory simulation of the AAW threat analysis problem was developed and embedded in an "air defense game" driven by a Tektronix 4051 microcomputer. This approach captured the important human information processing demands of AAW threat analysis by requiring sustained attention to a complex "hostile" environment that unfolded in real time and responded appropriately to the actions of the player. At the same time, the simulation scheme met the researchers' requirements for experimental control and for quantitative measurements of human performance. The computer is shown in Figure 1.

Scenario

The computer supervises an AAW scenario in which a player defends a ship by launching "missiles" at "hostile targets" that appear on the computer's CRT screen. Instructions given to the player appear in Figure 2. The goal is to kill all targets at maximum range, but the ship's detection range exceeds its weapons range so that a launch-time decision is necessary for each target. Missiles launched too early fall short of their targets (i.e., splash). It is possible to fire again after a splash, but only one missile is allowed to be in flight on a given track at one time. Duplicate (inflight) launches result in penalties. Penalties are also incurred, of course, when targets hit the ship.

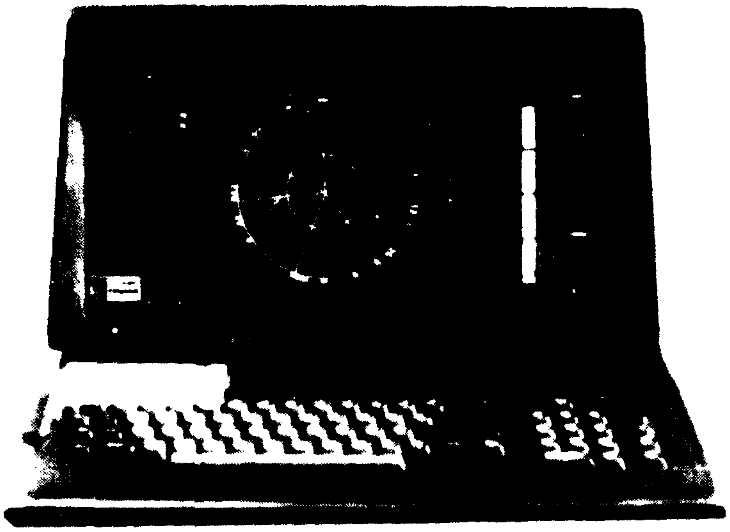


Figure 1. Computer displaying the air defense game in progress.

AIR DEFENSE GAME INSTRUCTIONS

YOUR SHIP IS UNDER ATTACK BY INCOMING MISSILES WITH VARYING SPEEDS AND LAUNCH TIMES. YOUR TASK IS TO MONITOR THE RADAR DISPLAY AND DESTROY THEM. THE PRIORITIES OF THE ENGAGEMENT ARE:

(1) AVOID BEING HIT.

(2) AVOID SPLASHING YOUR OWN MISSILES BY LAUNCHING TOO EARLY...YOUR WEAPONS RANGE IS 20 MILES, WHICH IS THE INNER CIRCLE OF THE RADAR DISPLAY.

(3) DESTROY INCOMING MISSILES AS SOON AS POSSIBLE AFTER THEY ENTER YOUR WEAPONS RANGE.

(4) AVOID LAUNCHING A MISSILE IF YOU ALREADY HAVE ONE IN FLIGHT ON THE SAME TARGET.

YOUR SKILL RATING (0-100) WILL INCLUDE A 12-POINT PENALTY FOR EACH HIT SUSTAINED AND A 2-POINT PENALTY FOR EACH INFLIGHT LAUNCH. THE MAXIMUM KILL RANGE IS 20 MILES. FIVE POINTS ARE DEDUCTED FOR EACH MILE THAT YOUR AVERAGE KILL RANGE IS UNDER 20.

TO LAUNCH A MISSILE, USE THE TEN WHITE KEYS AT THE UPPER LEFT OF THE KEYBOARD. ENTER THE TWO-DIGIT TRACK NUMBER OF THE TARGET...A READOUT WILL THEN INFORM YOU OF A SUCCESSFUL LAUNCH--OR AN ERROR. AN ERROR OCCURS IF YOU KEY A NUMBER INCORRECTLY OR IF YOU LAUNCH A MISSILE UNNECESSARILY.

GOOD LUCK....THE FATE OF YOUR SHIP LIES IN YOUR HANDS!

Figure 2. CRT display of instructions for air defense game.

Game Activity

Figure 3 shows a sample snapshot of the game in progress. The display simulates a radar screen in which the ship is the "+" sign at the center, the inner circle is the weapons range (20 miles), and the outer circle is the radar's detection range (46 miles). (The radius of the outer circle is 13.5 centimeters.) Targets appear as dots (blips) on the display and each is randomly assigned a unique track number (TN), 01 through 99, that appears at the outer circle as soon as the target enters the display. All targets head directly toward the ship at randomly selected bearings.

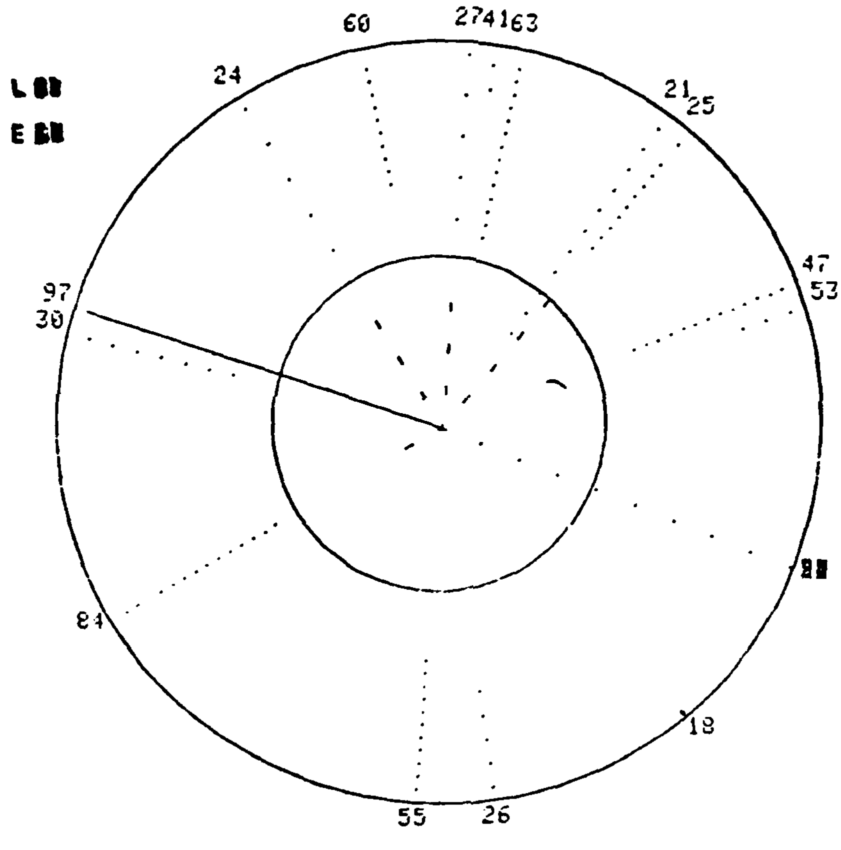


Figure 3. CRT display of a single update.

The computer, simulating a radar sweep, updates the display every 11.7 seconds, and at each update another blip is displayed on all target paths. The distance between blips, then, is a cue to the relative speed of the targets. In Figure 3, TN 24 is fast, TN 30 is medium, and TN 60 is slow; their respective speeds are 5, 3, and 1.6 miles per update. The sweep time varies from 0.6 to 0.8 seconds and the time between sweeps is available for action by the player and processing by the computer.

The player launches missiles by pressing function keys at the upper left of the computer's keyboard. Each keypress codes one digit of the required 2-digit TN. Feedback for a good launch (i.e., at a valid track) is indicated at the upper left of the display by flashing the keyed TN next to the letter "L" (for "launched"). An illegal launch attempt (i.e., for a nonexistent track or if a missile is already in flight on the track) is indicated by flashing the keyed TN next to the letter "E" (for "error").

When the player launches a missile, a dash (-) is immediately displayed to represent its path, and another dash is added at each update thereafter. Missiles, like fast targets, travel 5 miles per update. When the missile reaches its intended target, a kill occurs, a bell sounds, and the appropriate radius is filled by a solid line on the display. If an incoming target reaches the ship, a hit occurs, a longer bell sounds, and the TN of the target is blocked out.

In the example shown in Figure 3, the player has destroyed TN 97 and has sustained a hit from the target on the track at 4 o'clock. A missile has just been launched at TN 84, and missiles were launched against TNs 24 and 27 two sweeps earlier. A splash has occurred on TN 25; that missile reached weapons range too early to kill its assigned target.

Player Feedback

A single play of the game continues until each target in the scenario has either been killed or has hit the ship. The screen is then erased and the player is given feedback in the form of an air defense summary (see Figure 4). The "average range for kills" given in the summary is the mean distance from the ship to the points where targets were destroyed by missiles (hits are, of course, excluded from this computation). An overall "skill rating" (R) is provided that takes each of the engagement priorities into account. The rating is defined as:

R = 100 (Average kill range/20) - 12 (No. of hits) - 2 (No. of inflights).

```
                AIR DEFENSE SUMMARY

PLAYER NO. 10
NO. OF TARGETS = 18          TEMPO: INTERMEDIATE


SPEED          # KILLS            # HITS

FAST              5                  1
MEDIUM            6                  0
SLOW              6                  0

TOTAL KILLS = 17       TOTAL HITS = 1

AVERAGE RANGE FOR KILLS = 16.42        (MAX. = 20)

NO. OF MISSILES LAUNCHED = 18
NO. OF MISSILES SPLASHED = 1
NO. OF INFLIGHT LAUNCHES = 0


SKILL RATING = 70    (MAX. = 100)
Data is being stored on tape...

DO YOU WANT TO PLAY AGAIN (Y/N)?
```

Figure 4. Feedback information displayed at the end of each engagement.

If performance is perfect, all targets will be killed at the maximum range of 20 miles, there will be no hits or inflight launches, and R will be 100. While incurred penalties can render $R < 0$, $R = 0$ was the minimum value displayed as feedback to the player.

Task Variables

The major variables affecting the conduct of the air defense game are the number of targets, the tempo of operation, and target speed.

Number of Targets

The size of the computer's memory limits the number of targets presented in any engagement to 72. A displayed menu makes five selections available: 6 (for practice only), 18, 36, 54, or 72. Equal numbers of fast, medium, and slow targets are always assigned. The minimum separation between tracks is 4°.

Tempo of Operation

The tempo is also selected from a menu and controls, through one of three randomization routines, the rate at which the targets appear. In the low tempo, target entry times are relatively spread out and prosecuting the threats is comparatively easy. As the tempo is raised, the information processing demands increase. Entry time patterns, though varying with tempo and from engagement to engagement, always have the following characteristics:

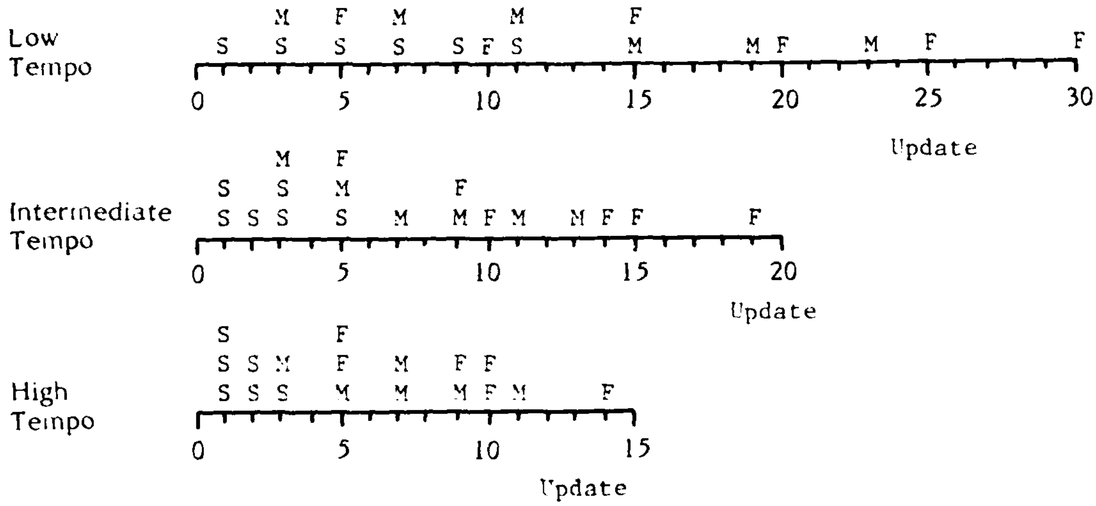
- Slow targets, which require the longest time to reach the ship, generally enter early in the engagement.

- Medium-speed targets enter most prominently during the middle of the engagement.

- Fast targets have their entries distributed over the entire engagement, except for their absence in the first several updates.

For any fixed number of targets, increasing the tempo increasingly crowds the times of entry. The effect is to shorten the engagement and yet preserve the patterns of entry times just described. This can be seen in Figure 5, which depicts the entry-time distributions of 18 targets for the three tempos. Each horizontal axis is the sequence of display updates, and the letters F, M, and S (six of each) indicate the entry of fast, medium, and slow targets. Each entry is stochastic (i.e., each target is equally likely to enter at its indicated update U or at U + 1). In effect, a fair coin is tossed separately for each of the 18 targets to determine its actual entry time in the given engagement.

The pattern of entry times given in Figure 5 does not imply a similar pattern for missile launches. Targets entering the display at different times with different speeds may very well enter the ship's missile range at the same time. The effect of each schedule is to create a peak demand for missile launches during the middle of each engagement.



Note. F, M, and S represent the entry of fast, medium, and slow targets. Each target is equally likely to enter at its indicated update U or at U + 1. Distributions shown are for the 18-target condition; these would be extended in time for larger numbers of targets.

Figure 5. Distribution of target entry times as a function of tempo.

For any engagement, the number of targets and the tempo combine to determine the number of updates to the entry of the last target, the mean number of updates between successive target arrivals, and the approximate duration of the engagement. The actual duration depends in part upon the player's proficiency in responding to those tracks that appear near the end of the game. Engagement characteristics are summarized in Table 1.

Target Speed

As previously stated, the three target speeds are 5.0, 3.0, and 1.6 miles per update, with initial ranges at entry being 45, 44, and 44 miles respectively. If the player fails to fire, a fast target will hit the ship at its 10th update; a medium target, at its 16th update; and a slow target, at its 28th update.

Performance Measurement and Analysis

A major advantage of on-line computerized control is that details of the player's behavior can be sensed and stored automatically. Here, each missile launch by the player is stored in memory and identified with its track number and the display update on which it occurred. The parameters and schedules of the targets also reside in memory. These data are stored on magnetic tape at the end of each game so that the engagement can be reconstructed for the experimenter and analyzed in detail.

A separate off-line analysis program retrieves the data from tape and displays an overall performance summary identical to that shown in Figure 4. Additional analyses provide the experimenter with more detailed summaries of the engagement. Fundamental to these analyses is the notion that there is an optimal launch time that can be used as a standard for player performance.

Table 1

Engagement Characteristics as Determined by the Number of Targets and the Tempo of Operation

Number of Targets	Tempo of Operation: Low	Intermediate	High
	Number of Updates to Last Target Entry[a]		
18	30	19	14
36	60	34	24
54	90	49	34
72	120	64	44
	Mean Number of Updates Between Successive Target Arrivals		
18	1.70	1.06	.76
36	1.68	.94	.66
54	1.68	.90	.62
72	1.68	.89	.60
	Duration of Engagement in Minutes[b]		
18	7.2	5.0	4.2
36	13.0	8.0	6.0
54	18.5	10.8	8.0
72	24.8	14.2	9.9

Note: Updates occur at intervals of approximately 11.7 seconds. The precise interval depends upon the status of the targets and the actions of the player.

[a]The randomization procedure, with probability = ½, adds one to the tabled value.

[b]These are approximate playing times for a single engagement. Actual durations vary somewhat with random scheduling effects and the proficiency of the player.

Optimal Launch Time

If player performance is optimal, each target will be destroyed at precisely the 20 mile weapons range circle. For a fast target entering the display at update E, the optimal launch time (L^*) is at update $E + 2$, which corresponds to the display of its third blip. For a medium target $L^* = E + 5$, its sixth blip. Similarly, for slow targets, we have $L^* = E + 12$.

As one performance measure, the player's actions are compared with the optimal tactics by taking the difference between observed launch time (L) and optimal launch time (L*) to yield the lag = L - L*. The ideal player will have zero lags for all targets, and increasing lags generally represent poorer performance by the player. If a target hits the ship, we arbitrarily assign a lag = - L*. Firing too early (a splash) would also result in a lag < 0, but subsequent behavior by the player--either a kill or allowing a hit to occur--determines the actual lag assigned to that target.

Target Information and Weapons Employment Summary

Figure 6 shows an example of a target information and weapons summary. For each of the 18 targets in this engagement, the top part of the display lists the target speed (F, M, or S) and the following:

- Bearing angle in degrees . . . . ANG
- Track number (01 through 99) . . . . TN
- Entry time (update number) . . . . E
- Optimal launch time (update number) . . . . L*
- Actual launch time (update number) L

		ANG	TN	E	L*	KL	LAG	IN	SP	O
1	F	112	46	5	7	0	-7	0	0	H
2	F	328	24	10	12	12	0	0	0	K
3	F	336	10	16	18	19	1	0	0	K
4	F	4	27	10	12	12	0	0	0	K
5	F	140	18	14	16	18	2	0	0	K
6	F	176	58	20	22	22	0	0	0	K
7	M	36	21	4	9	15	6	0	0	K
8	M	284	30	8	13	15	2	0	0	K
9	M	72	53	12	17	18	1	0	0	K
10	M	288	97	5	10	10	0	0	0	K
11	M	172	26	10	15	18	3	0	0	K
12	M	8	41	13	18	19	1	0	0	K
13	S	12	63	1	13	16	3	0	0	K
14	S	40	25	4	16	17	1	0	1	K
15	S	348	60	5	17	19	2	0	0	K
16	S	240	84	1	13	14	1	0	0	K
17	S	68	47	2	14	19	5	0	0	K
18	S	184	55	4	16	18	2	0	0	K

	MEAN LAG	SD LAG	N	IN	SP
FAST TARGETS	0.60	0.80	5	0	0
MED TARGETS	2.17	1.95	6	0	0
SLOW TARGETS	2.33	1.37	6	0	1
ALL TARGETS	1.76	1.66	17	0	1

Figure 6. Summary of target information and weapons employment for an 18-target engagement.

- Lag time (L - L*) . . . . LAG
- Number of inflight launches . . . . IN
- Number of splashes . . . . SP
- Outcome (K = target killed, H = hit on ship) . . . . O

The bottom of the display shows the mean lags and standard deviations (SD LAG) for each target speed and for all targets combined. The sample size (N) for these statistics includes only those targets that are killed by the player. Finally, the number of inflight launches (IN) and splashes (SP) are totaled for each target speed.

Dynamic Performance Summary

The above analyses refer to individual targets or to averages over targets of a given speed. As such, they do not capture the player's performance as the engagement unfolds in time. To obtain this kind of dynamic profile, the analysis program summarizes the situation at each update of the engagement. Figure 7 shows such a summary for an 18-target engagement concluded in 25 updates. The summary lists the following data:

- Update number . . . . U
- Number of active targets . . . . ACT
- Number of targets engaged by missiles . . . . ENG
- Cumulative number of targets killed . . . . K
- Cumulative number of hits on ship . . . . H
- Number of targets that remain scheduled to appear . . . . REM
- Number of unengaged targets within firing range . . . . UT
- Number of missed opportunities to fire at eligible targets . . . . MO

The UT and MO scores are candidate measures that seek to capture, at each update, the extent to which the player's actions are falling behind optimal performance. The UT measure is simply the number of eligible targets that have yet to be fired on at the current update.

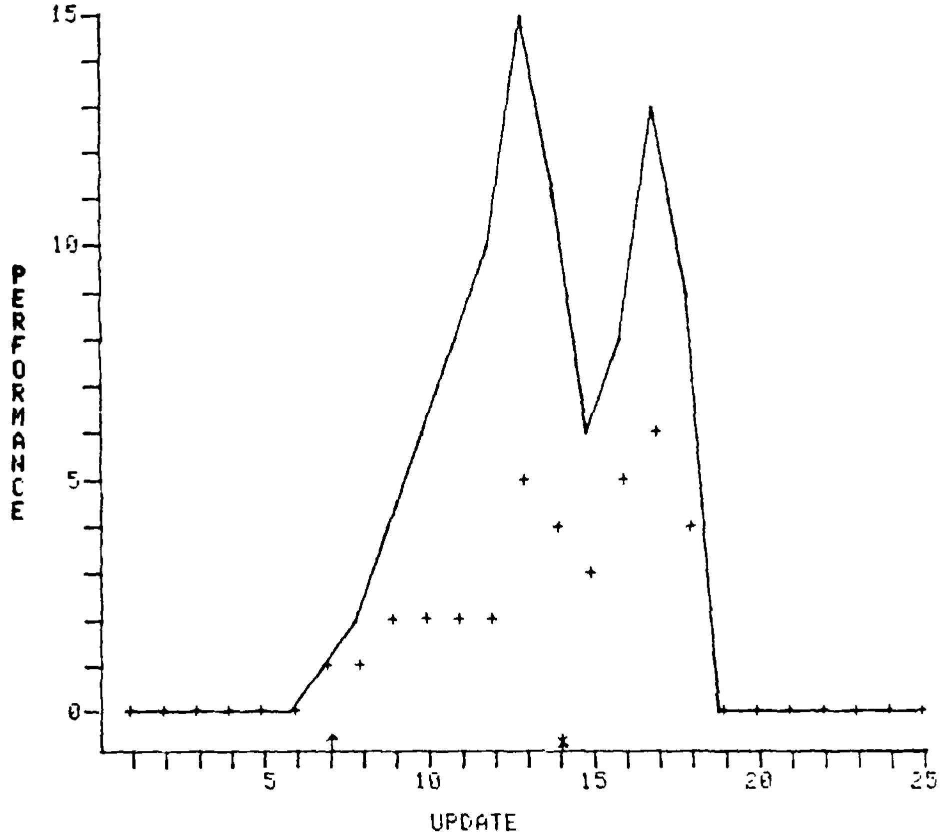
Note that the UT measure does not consider the number of prior updates on which a target has been eligible. The alternative measure MO includes this history. It is derived as follows: For the current update, denote the UT unengaged targets within range as $T_1,\ldots,T_{UT}$. Any such target, T_i, has been in this state for, say x_i updates including the current one. The measure MO is then the sum of the x_i for $i = 1,\ldots,UT$. Thus, it should be seen that MO is the number of missed opportunities to fire at eligible but unengaged targets. Equivalently, for any snapshot of the display at a given update, MO equals the total number of displayed blips within firing range for unengaged targets.

U	ACT	ENG	K	H	REM	UT	MO
1	2	0	0	0	16	0	0
2	3	0	0	0	15	0	0
3	3	0	0	0	15	0	0
4	6	0	0	0	12	0	0
5	9	0	0	0	9	0	0
6	9	1	0	0	9	0	0
7	9	1	0	0	9	1	1
8	10	1	0	0	8	1	2
9	10	1	0	0	8	2	4
10	13	1	0	0	5	2	6
11	13	1	0	0	5	2	8
12	14	3	0	0	4	2	10
13	14	2	1	0	3	5	15
14	14	3	1	1	2	4	11
15	12	3	3	1	2	3	6
16	12	3	4	1	1	5	8
17	11	3	5	1	1	6	13
18	10	6	6	1	1	4	9
19	9	9	7	1	1	0	0
20	7	6	10	1	0	0	0
21	4	3	13	1	0	0	0
22	1	1	16	1	0	0	0
23	1	1	16	1	0	0	0
24	1	1	16	1	0	0	0
25	0	0	17	1	0	0	0

Figure 7. Dynamic performance summary.

MO and UT, then, provide related measures of the player's efficiency as the engagement unfolds over time. It should be clear that MO $\geq$ UT and that, for an ideal player who fires at the optimal launch time, MO = UT = 0 for all updates. Real players, however, cannot process all targets as quickly as they become eligible.

A profile of MO and UT is displayed by the analysis program, as shown in Figure 8. For the UT index (the "+" signs), the first target came into firing range at the 7th update; the player did not launch a missile at that time, so UT = 1 for update 7. There were two eligible but unengaged targets on the updates 9 through 12, etc. As illustrated by the UT profile, this player progressively, and typically, fell behind optimal performance during the higher-paced middle portion of the engagement. The MO index (the solid line) reveals a similar impairment of performance during the period of peak processing demand. The asterisk in Figure 8 indicates that a hit was sustained on the 14th update.



Legend: + + + = number of unengaged targets within firing range.
——— = number of missed opportunities to fire at such targets.
↑ = first target enters firing range.
* = hit(s) sustained at this update.

Figure 8. Two performance indices as functions of update.

Hardware Characteristics

A Tektronix 4051 microcomputer controls the air defense simulation and the subsequent analyses of player performance. It has 32K bytes of memory, a direct-view storage tube display (19.1 cm by 14.0 cm), and a magnetic tape cartridge drive for storage of programs and data files. The programming language is Graphic System BASIC (Tektronix, 1976). The speed of graphic and arithmetic operations was enhanced by attaching an FP-51 Read-Only-Memory Pack.[1]

The keyboard has the standard typewriter layout, an auxiliary numeric entry keyset, and 10 user-definable function keys at the upper left. These latter were numbered from 0-9 and were used to enter track numbers to launch missiles. The function keys were the only ones used during engagements; a Plexiglas sheet covered the main keyboard to prevent inadvertent key presses.

Program Flow

The program listing for the air defense game appears in Appendix A; a list and description of variables is given in Appendix B. The program flow for the game is shown in Figure 9. The first part of the program (START to node B in the flowchart) provides instructions to the player and sets up the engagement parameters. The major section (nodes B to G) controls, for each update, the scheduled entry and display[2] of targets and missiles, tallies the player's actions and other events, and generally supervises the progress of the scenario. At the end of the engagement, the last section of the main program (Figure 9-c) controls the feedback display and the storage of data on magnetic tape. A special weapon-launching routine (Figure 9-d) interrupts the main program to process missile firings as they are keyed in by the player. From the player's perspective, the interrupt software causes no disruption of the flow of the game.

In the off-line data analysis program, the program flow is straightforward: the user selects the file to be analyzed and sequences through the displayed output. The program listing is in Appendix C; the variables and their descriptions are in Appendix D.

Limitations

The characteristics of the hardware and software impose the following limitations:

- Memory size limits the number of targets to 72.

- The 11.7 second interval between updates of the simulated radar display cannot be reduced while maintaining a constant inter-update interval for all combinations of the task variables. If desired, the interval can be increased by the straightforward insertion of a dummy routine.

---

[1]Micro Works, P.O. Box 1110, Del Mar, California 92014.

[2]To reduce variability in display timing, on every update the program has an inventory of 90 targets that are spaced 4° apart. Only the active ones are displayed; all others are suppressed.

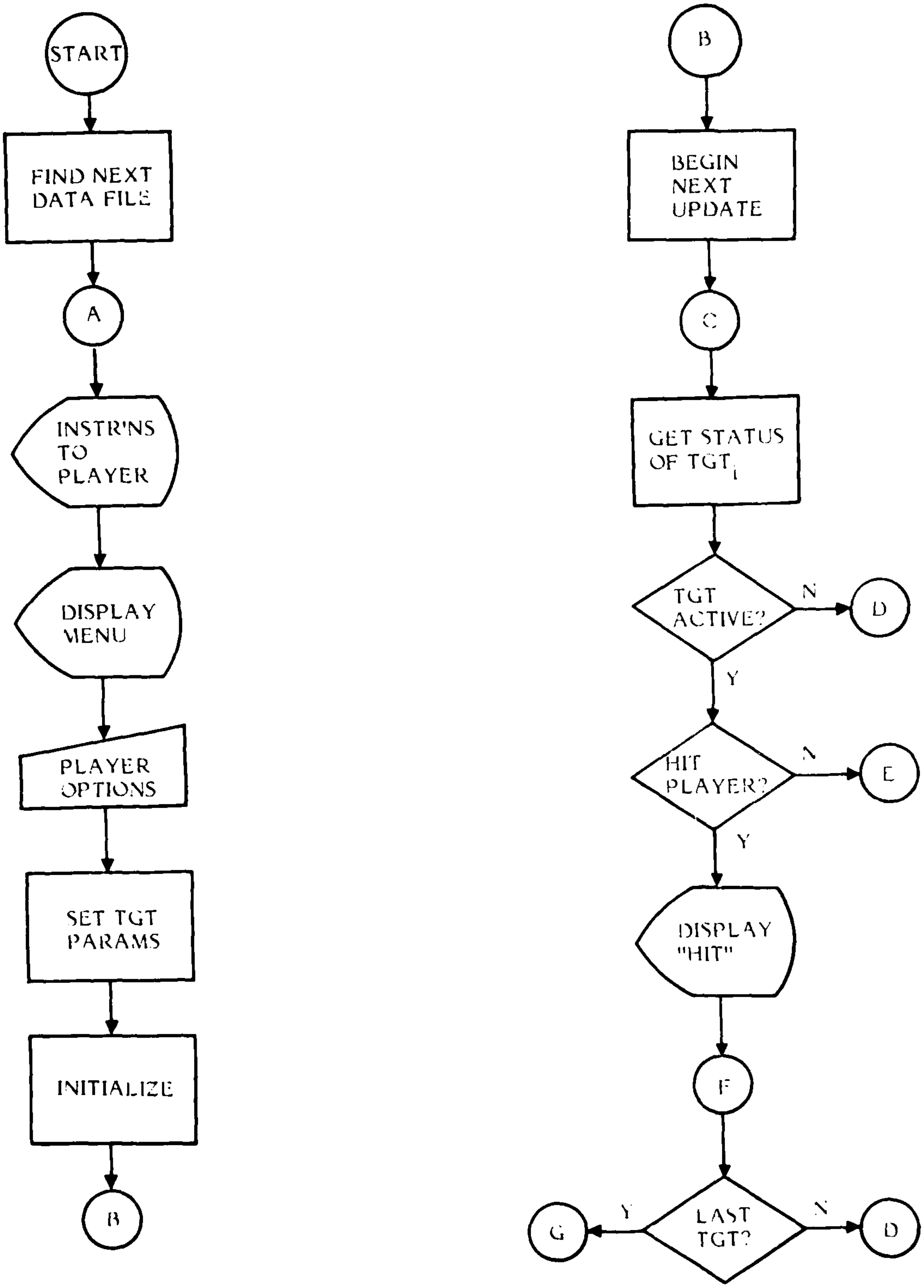


Figure 9a. Summary flowchart of air defense game.

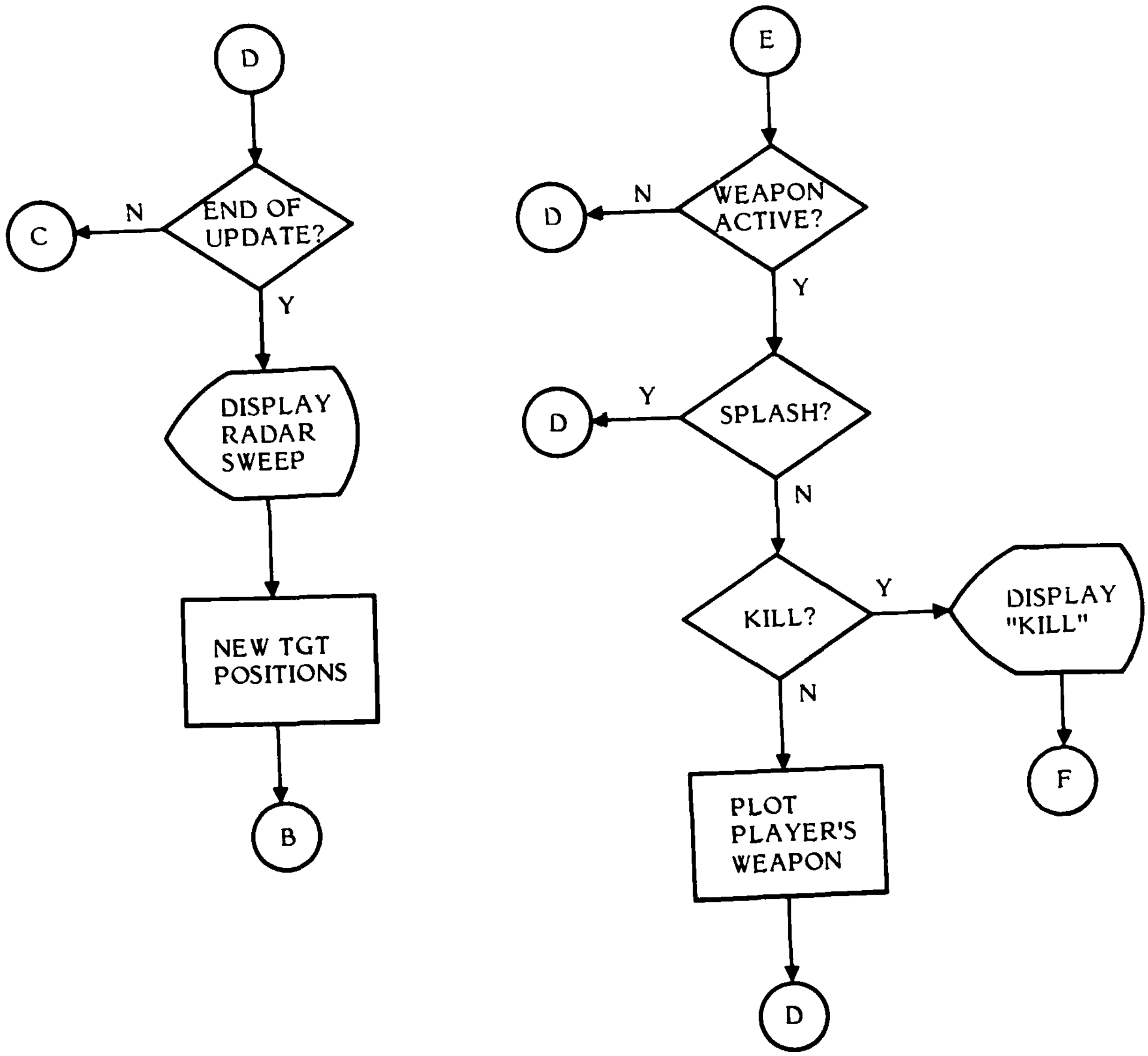

D
END OF UPDATE?
N
C
Y
DISPLAY RADAR SWEEP
NEW TGT POSITIONS
B
E
WEAPON ACTIVE?
N
D
Y
SPLASH?
Y
D
N
KILL?
Y
DISPLAY "KILL"
F
N
PLOT PLAYER'S WEAPON
D

Figure 9b.

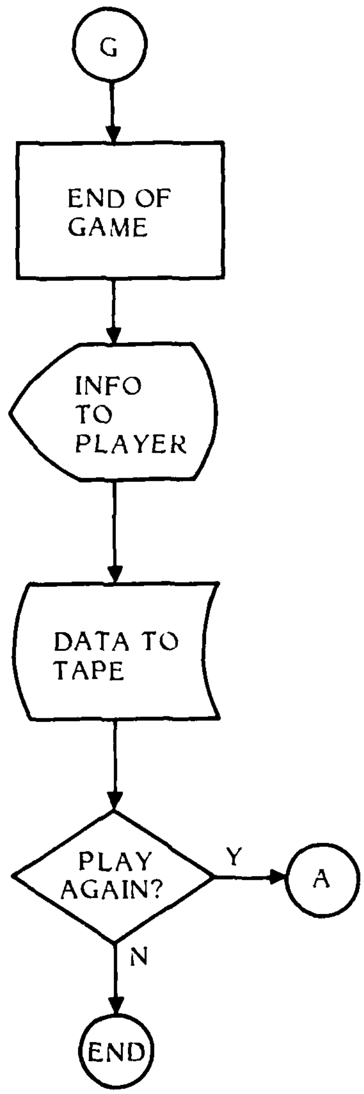


Figure 9c.

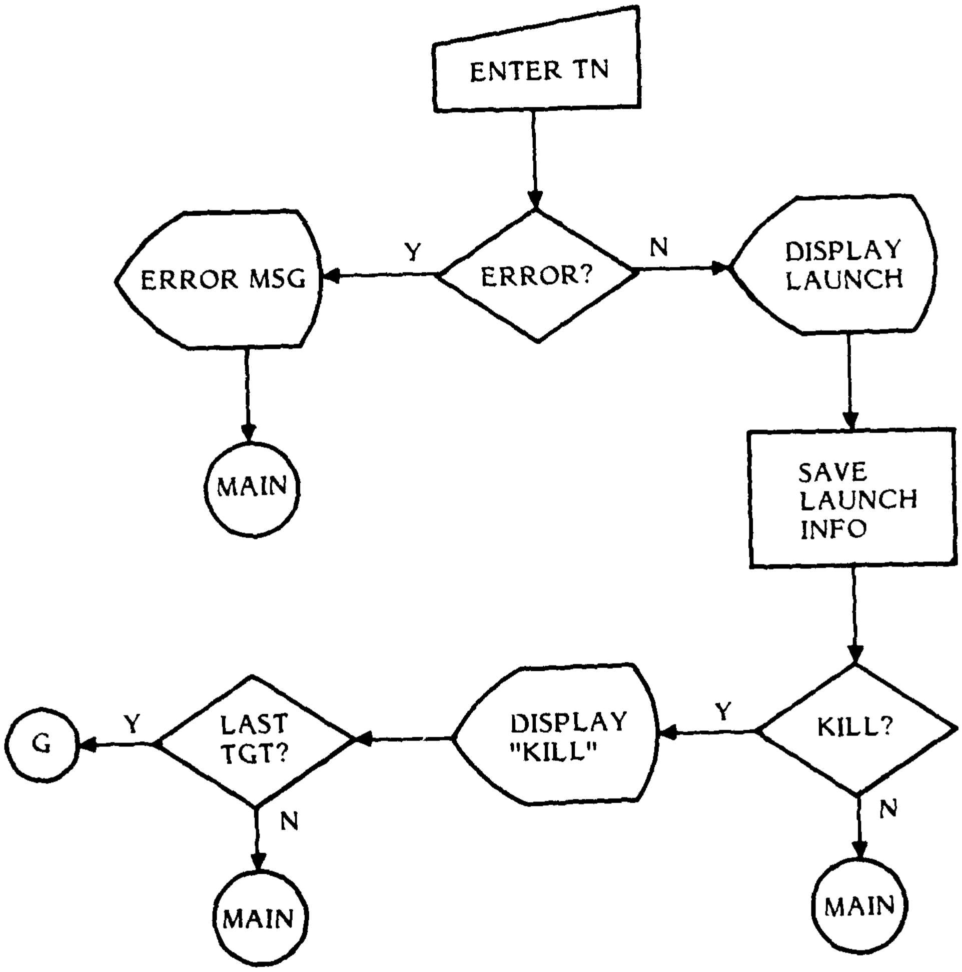

ENTER TN
ERROR?
Y
N
ERROR MSG
DISPLAY LAUNCH
MAIN
SAVE LAUNCH INFO
KILL?
Y
N
DISPLAY "KILL"
LAST TGT?
Y
N
G
MAIN
MAIN

Figure 9d.

- The display is a storage tube and cannot be selectively erased; thus, the paths of all targets and missiles must remain on the screen for the duration of the engagement. This tends to clutter the display when the number of targets is large.

- There is no provision for other than straight-line tracks. No change of target course is permitted.

- The function keys must be pressed and released quickly to avoid input errors. Practice sessions can serve, in part, to familiarize the user with proper striking of the keys.

- The program requires the FP-51 accessory pack in order to execute selected graphical and mathematical commands.

AN EXPERIMENT TO DEMONSTRATE FEASIBILITY

To demonstrate the feasibility of the air defense game as a research vehicle, volunteers were recruited to participate in a preliminary experiment. The experiment was exploratory and was designed to:

- Illustrate possible research uses of the air defense game.

- Checkout software and procedures in an on-line environment.

- Test the feasibility of extracting detailed measures of human performance.

- Ascertain the amount and type of training required to reach stable performance at moderate levels of difficulty.

- Derive indices of performance that are properly sensitive to variations in task load.

Subjects

The subjects were 17 Navy enlisted men (E-4 to E-6) waiting to enroll in advanced technical courses at the Naval Training Center, San Diego. Their median age was 19 years; the range was from 17 to 28. None of the subjects were experienced or trained in the use of computers. Participation was voluntary and informed consent was solicited in accordance with SECNAVINST 3900.39A.

Procedure

Two subjects were run at a time, each operating a separate computer. Neither subject could see the other's keyboard or display. The testing room was dimly illuminated in order to minimize glare on the display screens.

The subjects were first given a briefing that described the rationale for the experiment and gave an overview of the air defense game. This was followed by a detailed introduction to the game, the activities required during an engagement, and the type of feedback to the player. Participants next played two or three practice engagements to become familiar with the display and the data-entry keys. There were six targets, two at each speed, in each of the practice runs. The experimenter instructed the subjects in interpreting the display and in the proper use of the function keys. The experimenter emphasized the importance of avoiding hits on the ship and of killing targets at the greatest possible range, but no explicit rules were given as to when to fire. Rather, these were to be learned during the course of play.

After the briefing, practice, and instruction, the subjects began the training sequence proper. They were required to master each of four blocks of progressively more difficult types of engagements. Training was self-paced, and a skill rating of $R \geq 75$ on three consecutive engagements was the criterion for proficiency and the prerequisite for advancing to the next block. Two training sequences were used and subjects were assigned randomly to one or the other. The two sequences, denoted as A and B in Table 2, are identical in blocks 1 and 4. They both progress from an easy task (18 targets at low tempo) to a moderately difficult one (36 targets at high tempo).

Table 2

Number of Targets and Tempo of Operation in the Two Training Sequences

Training Sequence	Number of Targets-Tempo of Operation			
	Block 1	Block 2	Block 3	Block 4
A	18-low	18-intermediate	36-intermediate	36-high
B	18-low	36-low	18-high	36-high

Tempo was deemed to be more important than the number of targets in determining task difficulty. With this in mind, note that sequence B contains an abrupt shift in tempo, between blocks 2 and 3, and that sequence A provides two blocks of training in the intermediate tempo. It was hypothesized that subjects using sequence A would complete training more quickly.

After a subject reached criterion in block 4, ten additional engagements were run in the 36 target-high tempo condition. These were identical to those of block 4, except that there was a programmed 30 second rest period between engagements. At the end of the fifth engagement, an auditory monitoring task was introduced. The subject received instructions and six minutes of practice on the monitoring problem alone. Then, in engagements 6-10, both tasks were performed concurrently. The monitoring task continued during the 30-second breaks from the air defense game.

The monitoring task resembled a typical communications problem that might accompany AAW operations and was selected because of its minimal sensorimotor conflict with the air defense game. Specifically, the subject listened to a series of words and numbers and wrote down the digits that followed each occurrence of a preassigned word. Each message in the series consisted of a category (speed, altitude, etc.) followed by a 1-word call sign and a 3-digit random number. To illustrate, suppose the subject had been assigned the call sign YANKEE and had been presented the auditory input stream, "ALTITUDE BRAVO EIGHT-ZERO-SIX. . .SPEED YANKEE TWO-FOUR-THREE. . . ." The subject's task was to write "243" on a response sheet. For this subject, all messages with a call sign other than YANKEE were to be ignored.

The series of messages was recorded on tape and played through Audiotronics HS14 headphones at a rate of one message per 3.6 seconds. Thus, 100 messages would be presented in 6 minutes, which was the approximate duration of an engagement, including the rest period. Each of 10 different call signs appeared at 10 random times in every series. A given subject had the same call sign throughout all sessions.

Testing was scheduled for 3 hours on each of 2 consecutive days. At the end of testing, the subjects were interviewed for their evaluation of the task, and their questions about the experiment were answered.

Results

The feasibility of the software concept and its implementation were confirmed. The on-line collection of performance data proved feasible and straightforward, and there was no disruption to the user. Minor problems were found in the interrupt routine that services the function key inputs, and these were corrected in the final version of the program.

Due to an error in programming design, the inter-update interval in the experiment was allowed to vary from 7.0 seconds in the 18 target-low tempo condition to 9.8 seconds in the 36 target-high tempo condition. The resulting duration for these engagements ranged from 4.2 to 4.9 minutes. The effect of this variation was to give the subjects more time per update in the more difficult engagements. While this error did not affect our interpretation of the results that follow, it constituted an undesirable and unintentional manipulation. The program was modified to equate the intervals at 11.7 seconds for all 12 combinations of the tempo and number of targets. This modified version of the program appears in Appendix A and is the one recommended to potential users.

Skill Acquisition

Only 8 of the original 17 subjects completed the training regimen. Eight others had conflicting duty assignments and one failed, after 30 training engagements, to reach the performance criterion for Block 1; data for these subjects have been excluded from the analysis given below. Of the remaining eight subjects, three received training sequence A and five received sequence B. The overall mean number of engagements to complete the four blocks of training was 39.1 (median = 40; range = 19 to 73). The mean figure is equivalent to 2.9 hours of playing time.

The number of engagements required to complete the A and B sequences did not differ significantly by the Wilcoxon rank-sum test; the medians were 45 for sequence A and 35 for sequence B. This was contrary to the expectation that the A sequence would provide a smoother transition in difficulty and would thereby enhance acquisition. Apparently, the rate of acquisition was insensitive to both tempo and the number of targets. The Kruskal-Wallis test was employed to examine the interaction between blocks and training sequence (Bradley, 1968, pp. 138-141). The interaction was nonsignificant, indicating that performance for the four component blocks did not reliably differ as a function of the training sequence manipulation.

After collapsing the nonsignificant sequence variable, the median numbers of engagements to criterion were 9.0, 3.5, 5.5, and 13.0 for the Blocks 1-4 respectively. These differed reliably by the Friedman test, $S(3) = 153.5$, $p < .01$. It appears that once the basic skills of the game are acquired (in the easy condition of Block 1), then these are sufficient to prosecute engagements of moderate difficulty (Blocks 2-3). Additional skills must be mastered, however, to meet the increased demands of the 36 targets-high tempo condition of Block 4.

Because there were large individual differences in the number of engagements required to reach criterion, performance scores were Vincentized (see Hall, 1966, p. 64) into quartiles to further examine the course of acquisition. Figure 10 shows the mean skill rating (R) by quartile in each of the four training blocks. The positive trend within each block makes it clear that performance does indeed improve over the four quartiles. This effect was significant by a Friedman test, $\chi^2(3) = 19.7$, $p < .01$. Bradley's (1968) suggestions for extending the Friedman test were used to assess possible interactions; quartiles did not significantly interact with either block, $\chi^2(12) = 8.33$, or with the training sequence (A vs. B), $\chi^2(4) = 2.0$. Thus, the course of acquisition was similar within a training sequence and regardless of the sequence type.

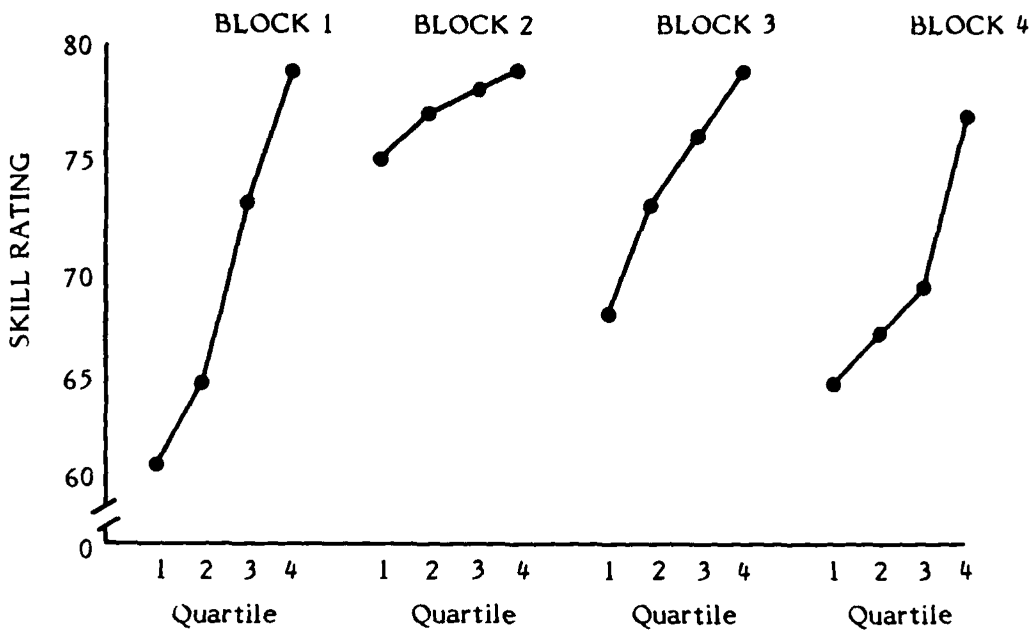
In summary, about 3 hours with either training regimen produced proficient performance in quite difficult air defense problems. The course of skill acquisition was insensitive to the variations in the sequence of engagement types. Basic skills were acquired largely through early practice and transferred readily to moderately difficult engagements. Significantly more practice was required to establish a high level of proficiency, though well short of mastery, in the more demanding air defense problems.

Dual-task Performance

Only five subjects were available to complete testing in the dual-task sessions. The skill ratings declined significantly when the auditory monitoring task was added to the air defense problem. Presumably, the information processing demands of the two concurrent tasks exceeded the subjects' resources. The differences between single- and dual-task performance are summarized in Table 3.

Analysis of other air defense game data corroborated the decrease in the skill rating observed in the dual-task condition. The range in miles at target intercept decreased while the number of hits on the ship, the number of inflight launches, and the number of splashes increased.

A decline in performance was also evident in the auditory monitoring task. When it was the sole task, performance was virtually perfect. When it was performed concurrently with the air defense game, detection of the call sign messages exhibited a small but significant decline. Most errors (92.3%) were due to omissions. From this pattern of results, it is clear that the subjects did not perform one task strictly at the expense of the other; rather, performance in both tasks was significantly affected.



Note. Data from training sequences A and B were combined.

Figure 10. Vincentized mean skill ratings (R) by quartile for the four training blocks.

Table 3

Comparison of Performance in Single- and Dual-Task Conditions

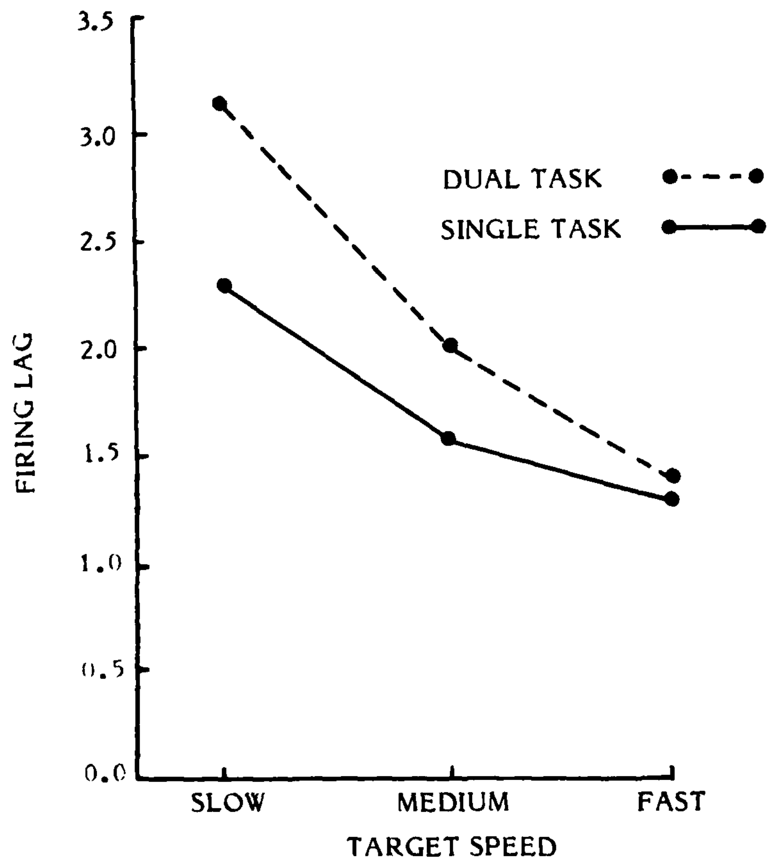
Performance Characteristic	Median Scores: Single-task Condition	Median Scores: Dual-task Condition	p[a]
Skill rating (R)	77.0	68.0	< .01
Target intercept (kill) range	15.8	15.0	< .01
Hits on ship	0.0	2.0	< .01
Inflight launches	3.5	6.7	< .025
Premature launches (splashes)	6.0	5.0	> .10
Monitoring task errors[b]	0.0	1.0	< .01

[a]Wilcoxon signed-rank test.

[b]The range of errors was 0 to 1 when the monitoring task was performed by itself; the range was 0-5 in the dual task condition.

The relation of task load (single vs. dual) and target speed (fast, medium, or slow) to the observed firing lag, L-L*, is shown in Figure 11. The auditory monitoring task significantly increased firing lags, $W(5) = 0$, $p < .05$, Wilcoxon signed-rank test. The main effect of target speed was also significant, $S(3,5) = 38$, $p < .05$ (Friedman test). Firing lags were longer for slow targets than for either fast or medium ones. We cite, as the most likely reason, the low priority that the rules impose on slow targets. Since they move a shorter distance between updates, smaller penalties are incurred (in terms of killing range) by firing at fast and medium speed targets.

The interaction between target speed and task load was not significant, suggesting that the demands of the monitoring task induced a general decrease in attention to the air defense game.



Note. A lag of 2 means that the player fired on the second update after the target entered firing range.

Figure 11. Mean firing lag as a function of target speed for single- and dual-task conditions.

Evaluation by Users

Unlike most laboratory tasks, the air defense game was fun and the subjects were able to maintain their interest in it for periods of 3 to 4 hours at a sitting. They reported that the feedback displayed at the end of each engagement was especially helpful in diagnosing their tactical weaknesses and in providing objective performance standards with which to monitor their progress. The capability for presenting engagements of varied difficulty was also regarded as a desirable feature.

CONCLUSIONS

This effort demonstrates that the air defense game is an effective vehicle for investigating human performance processes in AAW threat analysis. The game requires sustained attention to a complex and interactive "hostile" environment, provides proper experimental control of relevant variables, and affords detailed quantitative measurements of human performance that can be compared to that of a mathematically ideal information processor. The hardware/software system provides flexibility and portability in an inherently motivating task that taps the cognitive skills required in selected command and control environments.

Proficient performance can be attained with moderate amounts of practice. Variations in the number of targets, target speed, and the pace of operations produce reliable effects on performance. The task is sensitive to the workload demands of a concurrent auditory monitoring task.

RECOMMENDATIONS

1. The air defense game should be exploited as a tool in future research on the threat analysis problem.

2. The air defense game should be used to determine limitations in human information processing and how strategies for threat analysis change as a function of task load.

3. Performance in the air defense simulation should be used as a dependent measure for other military research applications (e.g., the effect of extended effort or sleep loss).

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APPENDIX A

AIR DEFENSE GAME: PROGRAM LISTING

```
2 RUN 170
3 REM----------function key servicing
4 T$=T$&"1"
6 GOSUB A OF 2690,50
7 RETURN
8 T$=T$&"2"
10 GOSUB A OF 2690,50
11 RETURN
12 T$=T$&"3"
14 GOSUB A OF 2690,50
15 RETURN
16 T$=T$&"4"
18 GOSUB A OF 2690,50
19 RETURN
20 T$=T$&"5"
21 GOSUB A OF 2690,50
22 RETURN
24 T$=T$&"6"
26 GOSUB A OF 2690,50
27 RETURN
28 T$=T$&"7"
30 GOSUB A OF 2690,50
31 RETURN
32 T$=T$&"8"
34 GOSUB A OF 2690,50
35 RETURN
36 T$=T$&"9"
38 GOSUB A OF 2690,50
39 RETURN
40 T$=T$&"0"
41 GOSUB A OF 2690,50
42 RETURN
49 REM----------inappropriate keypress
50 T$=""
60 RETURN
98 REM
99 REM
100 REM                     AIR DEFENSE GAME
110 REM
120 REM          R. L. Hershman, F. L. Greitzer, & R. T. Kelly
130 REM           Command and Support Systems, Code 302
140 REM           Navy Personnel Research & Development Center
150 REM                   San Diego, CA 92152
160 REM
170 REM----------find next data file
180 PRINT @33,0:0,0,1
190 F1=5
200 FIND F1
210 INPUT @33:A$
220 A$=SEG(A$,9,1)
230 IF A$="L" THEN 260
240 F1=F1+1
250 GO TO 200
260 PRINT @33,0:0,0,0
270 SET DEGREES
280 SET NOKEY
290 A=2
300 Z=RND(-1)
310 REM----------print instructions
320 PRINT "LIHHHHHHAIR DEFENSE GAME INSTRUCTIONS__     YOUR SHIP IS U";
330 PRINT "NDER ATTACK BY INCOMING MISSILES WITH_VARYING SPEEDS AND";
340 PRINT " LAUNCH TIMES.  YOUR TASK IS TO MONITOR_THE RADAR DISPLAY";
350 PRINT " AND DESTROY THEM.  THE PRIORITIES_OF THE ENGAGEMENT ARE:_"
360 PRINT "    (1) AVOID BEING HIT.__     (2) AVOID SPLASHING YOUR OWN ";
370 PRINT "MISSILES BY LAUNCHING TOO_         EARLY...YOUR WEAPONS ";
380 PRINT "RANGE IS 20 MILES, WHICH_          IS THE INNER CIRCLE OF THE";
390 PRINT " RADAR DISPLAY.__    (3) DESTROY INCOMING MISSILES AS SOON ";
400 PRINT "AS POSSIBLE_         AFTER THEY ENTER YOUR WEAPONS RANGE._"
410 PRINT "    (4) AVOID LAUNCHING A MISSILE IF YOU ALREADY HAVE ONE"
420 PRINT "          IN FLIGHT ON THE SAME TARGET.__     YOUR SKILL RATI";
430 PRINT "NG (0-100) WILL INCLUDE A 12-POINT_PENALTY FOR EACH HIT ";
440 PRINT "SUSTAINED AND A 2-POINT PENALTY FOR_EACH INFLIGHT LAUNCH. ";
450 PRINT " THE MAXIMUM KILL RANGE IS 20 MILES._FIVE POINTS ARE DEDUC";
460 PRINT "TED FOR EACH MILE THAT YOUR AVERAGE_KILL RANGE IS UNDER 20."
470 PRINT "J     TO LAUNCH A MISSILE, USE THE TEN WHITE KEYS AT THE";
```

```
480 PRINT " UPPER_LEFT OF THE KEYBOARD   ENTER THE TWO-DIGIT ",
490 PRINT "TRACK NUMBER_OF THE TARGET.  A READOUT WILL THEN INFORM ";
500 PRINT "YOU OF A SUCCESSFUL_LAUNCH--OR AN ERROR   ",
510 PRINT "AN ERROR OCCURS IF YOU KEY A NUMBER_INCORRECTLY",
520 PRINT " OR IF YOU LAUNCH A MISSILE UNNECESSARILY "
530 PRINT "J GOOD LUCK..  THE FATE OF YOUR SHIP LIES IN YOUR HANDS!"
540 PRINT "J         Press RETURN to continue.   ";
550 INPUT A$
560 REM----------cleanup memory and get player I D.
570 PRINT "LJJENTER YOUR NAME    ";
580 INPUT S$
590 Z1=0
600 T7=54
610 M$="L##"
620 N$="E##"
630 DELETE P3,S3,F3,G3,K3,L3,X9,K5,T$,A6,A7,A8,A9,H9,L$,A1,A5,A4,W,T2
640 SET NOKEY
650 A=2
660 T$=""
670 REM----------select tempo and target density
680 W$="LOW          "
690 X$="INTERMEDIATE   "
700 Y$="HIGH          "
710 O$="Practice"
720 PRINT "JJSELECT TEMPO._    1=",W$,"_    2=",X$,"_    3=",Y$
730 PRINT "    4=";O$;"            ",
740 INPUT D
750 IF D<1 OR D>4 THEN 740
760 IF D<>4 THEN 810
770 N0=2
780 K=2
790 W7=443
800 GO TO 890
810 PRINT "JJJSELECT TARGET DENSITY (1, 2, 3, OR 4): ",
820 INPUT N0
830 IF N0<1 OR N0>4 THEN 820
840 N0=N0*6
850 K=N0/D
860 REM----------set W7 counter to equate update times
870 A$=SEG("083095100025022018010006002004001000",3*N0/2+3*D-11,3)
880 W7=VAL(A$)
890 N=3*N0
900 W8=N=72 AND D=3
910 PRINT "JJJWe'll begin in a few seconds . "
920 DIM A5(N),R1(N)
930 REM----------randomization for entry times
940 CALL "FLASH"
950 R1=INT(RND(1)+0.5)
960 FOR I=1 TO K
970 GO TO D OF 1040,1010,980,1040
980 A5(I+2*K)=5*I+R1(I+2*K)
990 A5(I+2*K+N0)=4*I+3+R1(I+2*K+N0)
1000 A5(I+2*K+2*N0)=I+R1(I+2*K+2*N0)
1010 A5(I+K)=5*I+4+R1(I+K)
1020 A5(I+K+N0)=4*I+1+R1(I+K+N0)
1030 A5(I+K+2*N0)=I+R1(I+K+2*N0)
1040 A5(I)=5*I+R1(I)
1050 A5(I+N0)=4*I-1+R1(I+N0)
1060 A5(I+2*N0)=2*I-1+R1(I+2*N0)
1070 NEXT I
1080 REM----------assign track nos, speeds, angles, and hit times
1090 DIM P3(90),S3(90),H9(N),L$(1200),A1(90),A8(90),A9(90),X9(90),W(N)
1100 S3=0
1110 CALL "MFLASH"
1120 A1=FNX(4)
1130 A8=FNX(1)+9
1140 W=FNX(1)
1150 REM
1160 FOR K=1 TO 90
1170 B=A1(K)
1180 C=A8(K)
1190 CALL "MFLASH"
1200 J=INT(RND(1)*90)+1
1210 J1=INT(RND(1)*90)+1
1220 REM
1230 A1(K)=A1(J)
```

```
1240 A1(J)=B
1250 A8(K)=A8(J1)
1260 A8(J1)=C
1270 NEXT K
1280 DIM A1(N),A8(N),A4(N)
1290 FOR I=1 TO N
1300 A9(I)=A1(I)/4
1310 IF I<=N0 THEN 1390
1320 IF I<=2*N0 THEN 1360
1330 A4(I)=28+A5(I)
1340 S3(A9(I))=1.6
1350 GO TO 1410
1360 A4(I)=16+A5(I)
1370 S3(A9(I))=3
1380 GO TO 1410
1390 A4(I)=10+A5(I)
1400 S3(A9(I))=5
1410 NEXT I
1420 REM----------draw circles
1430 PAGE
1440 DIM X(101),Y(101),T2(N)
1450 Z0=46
1460 GOSUB 1500
1470 Z0=20
1480 GOSUB 1500
1490 GO TO 1570
1500 CALL "MFLASH"
1510 X=SIN(FNX(3.6))*Z0+T7
1520 Y=COS(FNX(3.6))*Z0+50
1530 X(1)=-X(1)
1540 REM
1550 CALL "DFLASH",X,Y
1560 RETURN
1570 MOVE T7-0.5,48.5
1580 PRINT @32,18:5
1590 PRINT "+↑____";M$;"J__";N$
1600 DELETE X,Y,R1
1610 REM----------initialize
1620 DIM F3(90),G3(90),K3(180),L3(180),T$(20),A6(N),A7(N),K5(N)
1630 U=1
1640 K1=0
1650 K9=0
1660 L7=0
1670 L8=0
1680 L9=0
1690 A6=0
1700 A7=0
1710 P3=44
1720 FOR I=1 TO N0
1730 P3(A9(I))=45
1740 NEXT I
1750 H0=0
1760 X9=0
1770 H9=1
1780 L1=1
1790 SET KEY
1800 A=1
1810 REM----------start new epoch
1820 K4=0
1830 H=1
1840 CALL "FLASH"
1850 A6=ABS(A6)*H9
1860 H9=1
1870 REM----------determine target status
1880 FOR I0=1 TO N
1890 GO TO 2*(A5(I0)>U)+W8 OF 1900,2330,1980
1900 IF U=A4(I0) THEN 3420
1910 X9(A9(I0))=1
1920 IF P3(A9(I0))<44 THEN 1960
1930 K4=K4+1
1940 K5(K4)=I0
1950 GO TO 1980
1960 GO TO A6(I0)+1 OF 1980,2370
1970 A6(I0)=1
1980 NEXT I0
1990 REM----------make radar sweep
```

```
2000 CALL "MFLASH"
2010 F3=(2*X9-1)*(SIN(FNX(4))*P3+T7)
2020 G3=COS(FNX(4))*P3+50
2030 REM
2040 FOR I=1 TO 90
2050 CALL "MFLASH"
2060 J1=2*I-1
2070 K3(J1)=F3(I)
2080 K3(J1+1)=F3(I)
2090 L3(J1)=G3(I)
2100 L3(J1+1)=G3(I)
2110 REM
2120 NEXT I
2130 CALL "XFLASH"
2140 K3=-ABS(K3)
2150 H=-1
2160 CALL "DFLASH",K3,L3
2170 IF K4=0 THEN 2280
2180 REM----------display target nos.
2190 FOR J2=1 TO K4
2200 CALL "MFLASH"
2210 X7=SIN(A1(K5(J2)))*48.5+T7+0.5
2220 Y7=COS(A1(K5(J2)))*48.5+49
2230 REM
2240 MOVE X7,Y7
2250 PRINT "H",A8(K5(J2));
2260 NEXT J2
2270 REM----------compute next position
2280 CALL "FLASH"
2290 P3=P3-X9*S3
2300 P3=0 MAX P3
2310 U=U+1
2320 GO TO 1820
2330 FOR W6=1 TO W7
2340 NEXT W6
2350 GO TO 1980
2360 REM----------plot player's missile track
2370 A7(I0)=A7(I0)+5
2380 IF A7(I0)>20 THEN 2500
2390 IF P3(A9(I0))+S3(A9(I0))-A7(I0)<=0.1 THEN 2550
2400 CALL "MFLASH"
2410 X1=SIN(A1(I0))*A7(I0)+T7
2420 Y1=COS(A1(I0))*A7(I0)+50
2430 X2=SIN(A1(I0))*(A7(I0)-1)+T7
2440 Y2=COS(A1(I0))*(A7(I0)-1)+50
2450 REM
2460 MOVE X1,Y1
2470 DRAW X2,Y2
2480 GO TO 1980
2490 REM----------missile splashed
2500 L8=L8+1
2510 A7(I0)=0
2520 A6(I0)=0
2530 GO TO 1980
2540 REM----------destroyed a target
2550 PRINT "G";
2560 MOVE T7,50
2570 ROTATE 90-A1(I0)
2580 RDRAW 45,0
2590 X9(A9(I0))=0
2600 K9=K9+P3(A9(I0))+S3(A9(I0))
2610 A5(I0)=A5(I0)+2000
2620 A6(I0)=0
2630 K1=K1+1
2640 IF K1+H0<>N THEN 1980
2650 I0=N
2660 NEXT I0
2670 GO TO 3560
2680 REM----------assemble target no. for launch
2690 GO TO LEN(T$)+1 OF 2700,3320,2730
2700 T$=SEG(T$,1,2)
2710 GIN X6,Y6
2720 GO TO 3240
2730 T0=VAL(T$)
2740 GIN X6,Y6
2750 REM----------lookup target #
```

```
2760 T2=T0=A8
2770 T2=T2*W
2780 J=SUM(T2)
2790 IF J=0 THEN 3210
2800 IF ABS(A6(J))=1 THEN 3180
2810 IF X9(A9(J))=0 THEN 3210
2820 CALL "MFLASH"
2830 X3=SIN(A1(J))*5+T7
2840 Y3=COS(A1(J))*5+50
2850 X4=SIN(A1(J))*4+T7
2860 Y4=COS(A1(J))*4+50
2870 REM
2880 REM----------launch the missile
2890 MOVE X3,Y3
2900 DRAW X4,Y4
2910 A6(J)=-1
2920 H9(J)=H
2930 A7(J)=5
2940 L9=L9+1
2950 I$=STR(600+A8(J))
2960 GOSUB 3340
2970 REM----------good launch.. inform player
2980 FOR S=1 TO 6
2990 MOVE 1.792+Z)*5.376,86.912
3000 PRINT T$;
3010 FOR S1=1 TO 8
3020 NEXT S1
3030 NEXT S
3040 IF P3(A9(J))+S3(A9(J))>5 THEN 3300
3050 REM----------destroyed target
3060 PRINT "G";
3070 MOVE T7,50
3080 ROTATE 90-A1(J)
3090 RDRAW 45,0
3100 X9(A9(J))=0
3110 A6(J)=0
3120 K9=K9+0 MAX P3(A9(J))+S3(A9(J))
3130 A5(J)=A5(J)+2000

3140 K1=K1+1
3150 IF K1+H0<>N THEN 3300
3160 GO TO 3560
3170 REM----------error:in-flight launch
3180 L7=L7+1
3190 I$=STR(700+A8(J))
3200 GOSUB 3340
3210 REM----------error.. inform player
3220 GOSUB 3240
3230 RETURN
3240 FOR S=1 TO 6
3250 MOVE 1.792+Z1*5.376,78 464
3260 PRINT T$;
3270 FOR S1=1 TO 8
3280 NEXT S1
3290 NEXT S
3300 MOVE X6,Y6
3310 T$=""
3320 RETURN
3330 REM.... load L$ with launch Information
3340 H$=STR(U+99 5-H/2)
3350 H$=SEG(H$,2,3)
3360 I$=SEG(I$,2,3)
3370 H$=H$&I$
3380 L$=REP(H$,L1,0)
3390 L1=L1+6
3400 RETURN
3410 REM----------target hit player's ship
3420 H0=H0+1
3430 A5(I0)=A5(I0)+1000
3440 X9(A9(I0))=0
3450 PRINT "GGG";
3460 CALL "MFLASH"
3470 X8=SIN(A1(I0))*48.5+T7+0.5
3480 Y8=COS(A1(I0))*48.5+49
3490 REM
3500 MOVE X8,Y8
3510 PRINT "H**";
```

```
3520 IF K1+H0<>N THEN 1980
3530 I0=N
3540 NEXT I0
3550 REM-----------end of game
3560 MOVE 0.4
3570 PRINT "End of game    "
3580 A=2
3590 FOR I=1 TO 700
3600 J=J
3610 NEXT I
3620 SET NOKEY
3630 REM-----------summarize performance
3640 DIM C1(3),C2(3),V$(15)
3650 C1=0
3660 C2=0
3670 FOR K=1 TO 3
3680 FOR I=(K-1)*N0+1 TO K*N0
3690 IF A5(I)<2000 THEN 3720
3700 C2(K)=C2(K)+1
3710 GO TO 3730
3720 C1(K)=C1(K)+1
3730 NEXT I
3740 NEXT K
3750 IF K1=0 THEN 3770
3760 K9=K9/K1
3770 PRINT "LIHHHHHHAIR DEFENSE SUMMARY__";S$;"__NO  OF TARGETS = ";N;
3780 GO TO D OF 3790,3810,3830,3840
3790 O$=W$
3800 GO TO 3840
3810 O$=X$
3820 GO TO 3840
3830 O$=Y$
3840 PRINT @32,18:0
3850 PRINT "       TEMPO: ";O$;"__SPEED          # KILLS            # HITS _"
3860 V$="FAST"
3870 PRINT USING 3920:V$,C2(1),C1(1)
3880 V$="MEDIUM"
3890 PRINT USING 3920:V$,C2(2),C1(2)
3900 V$="SLOW"
3910 PRINT USING 3920:V$,C2(3),C1(3)
3920 IMAGE  8A,10D,16D
3930 PRINT "JTOTAL KILLS = ";SUM(C2);"       TOTAL HITS = ";SUM(C1)
3940 PRINT USING """JAVERAGE RANGE FOR KILLS = ""2D.2D" K9
3950 PRINT "KIJ(MAX  = 20)"
3960 R$="_NO  OF MISSILES "
3970 PRINT R$;"LAUNCHED = ";L9+L7,R$;"SPLASHED = ";L8
3980 PRINT "NO. OF INFLIGHT LAUNCHES = ";L7
3990 R=INT(100*K9/20-12*SUM(C1)-2*L7)
4000 PRINT "JJSKILL RATING = ";R MAX 0;"    (MAX  = 100)"
4010 IF O$="PRACTICE" THEN 4120
4020 REM-----------store data on tape
4030 PRINT "Data is being stored on tape.  "
4040 L=LEN(L$)
4050 FIND F1
4060 MARK 1,30*N+300+L
4070 FIND F1
4080 U=U+0.5-H/2
4090 WRITE @33:S$,D,N,A1,A5,A8,L,L$,C1,C2,K9,L9,L8,L7,R,U
4100 CLOSE
4110 F1=F1+1
4120 PRINT "JDO YOU WANT TO PLAY AGAIN (Y/N)? ";
4130 INPUT A$
4140 IF A$="Y" THEN 4180
4150 IF A$<>"N" THEN 4130
4160 PRINT "JTHANK YOU"
4170 END
4180 REM----------Set display parameters for next game
4190 PAGE
4200 A=2
4210 T$=""
4220 SET NOKEY
4230 M$="   "&M$
4240 N$="   "&N$
4250 Z1=Z1+1
4260 T7=T7+5.376
4270 GO TO (Z1=5)+1 OF 630,590
```

APPENDIX B

AIR DEFENSE GAME: PROGRAM VARIABLES

VARIABLE NAME	DEFINITION	TYPE
A	Switch for servicing function keys	Simple
A$	Tape file header	String
A1	Target bearing(degrees)	Array(N)
A4	Update at which target will hit own ship	Array(N)
A5	Target entry time: plus 1000(hit) or 2000 (killed)	Array(N)
A6	Own missile status (1=in flight)	Array(N)
A7	Own missile position	Array(N)
A8	Target track number(TN)	Array(N)
A9	Code for target bearing=A1/4	Array(N)
B	Temporary storage: bearing randomization	Simple
C	Temporary storage: TN randomization	Simple
C1	No. of hits (fast, medium, slow)	Array(3)
C2	No. of kills (fast, medium, slow)	Array(3)
D	Tempo of operations	Simple
F1	Magtape data file no.	Simple
F3	X-coordinate for target display	Array(90)
G3	Y-coordinate for target display	Array(90)
H	Missile status	Simple
H$	Launch data: 6 digits	String
H0	No. of hits on own ship	Simple
H9	Missile status	Array(N)
I	Index in for-next loop	Simple
I$	Launch information	String
I0	Index in for-next loop	Simple
J	Index in bearing randomization	Simple
J1	Index in TN randomization	Simple
J2	Index in for-next loop	Simple
K	Loop control: N0/D	Simple
K1	No. of kills	Simple

VARIABLE NAME	DEFINITION	TYPE
K3	Radar sweep array for FP-51	Array(180)
K4	No. of targets entering this update	Simple
K5	Pointer to targets that enter this update	Array(N)
K9	Accumulator for killing range	Simple
L	Final length of L$	Simple
L$	Player's launch history	String
L1	Current length of L$	Simple
L3	Radar sweep array for FP-51	Array(180)
L7	No. of inflight launches	Simple
L8	No. of splashes	Simple
L9	No. of good launches	Simple
M$	Display of launch status	String
N	Total no. of targets	Simple
N$	Display of launch status	String
NO	No. of targets of each speed	Simple
P3	Target range	Array(N)
Q$	Text	String
R	Skill rating	Simple
R$	Text for feedback	String
R1	0's or 1's for entry time randomization	Array(N)
S	Index for flashing TN display	Simple
S$	Player I.D.	String
S1	Index for flashing TN display	Simple
S3	Target speed	Array(N)
T$	Input of launch data	String
TO	2-digit launch data	Simple
T2	Array for track number lookup	Array(N)
T7	X-coordinate for own ship	Simple
U	Update counter	Simple
V$	Text	String

VARIABLE NAME	DEFINITION	TYPE
W	Track number lookup: 1, 2,...,N	Array(N)
W$	Text	String
W6	Index in for-next loop	Simple
W7	Counter to equate inter-update intervals	Simple
W8	Logical switch for game parameters 1 = high tempo, N = 72; 0 = otherwise	Simple
X	X-coordinate for display of circle	Array(101)
X$	Text	String
X1	X-coordinate for missile track: origin	Simple
X2	X-coordinate for missile track: terminus	Simple
X3	X-coordinate for missile track: origin	Simple
X4	X-coordinate for missile track: terminus	Simple
X7	X-coordinate to display track number	Simple
X8	X-coordinate to overwrite track number	Simple
X9	Target status for display: 0 = inactive; 1 = active	Array(90)
Y	Y-coordinate for display of circle	Array(101)
Y1	Y-coordinate for missile track: origin	Simple
Y2	Y-coordinate for missile track: terminus	Simple
Y3	Y-coordinate for missile track: origin	Simple
Y4	Y-coordinate for missile track: terminus	Simple
Y7	Y-coordinate to display track number	Simple
Y8	Y-coordinate to overwrite track number	Simple
Z	Dummy variable	Simple
Z0	Radius of circle	Simple
Z1	Counter for repositioning display	Simple

APPENDIX C

DATA ANALYSIS: PROGRAM LISTING

```
100 REM           AIR DEFENSE GAME: DATA ANALYSIS
110 REM
120 REM   R. L. Hershman, F. L. Greitzer, & R. T. Kelly
130 REM            Command and Support Systems
140 REM    Navy Personnel Research & Development Center
150 REM                    Code 302
160 REM              San Diego, CA 92152
170 REM
180 INIT
190 PRINT "LENTER FILE NO.: ";
200 INPUT F$
210 FIND VAL(F$)
220 READ @33:S$,D,N
230 DIM A1(N),A5(N),A8(N),O(N,5),C1(3),C2(3),W(99),Y(3,4)
240 READ @33:A1,A5,A8,L
250 DIM L$(L+1)
260 READ @33:L$,C1,C2,K9,L9,L8,L7,R1,U
270 REM   .......Display Data Summary
280 T$="FILE #"&F$
290 PRINT "LIAIR DEFENSE GAME SUMMARY:";T$;"__";S$
300 C$=SEG("LOW         INTERMEDIATEHIGH        ",12*(D-1)+1,12)
310 PRINT "JJN= ";N;"  ";C$;"__SPEEDIKILLSIHITSJ"
320 FOR I=1 TO 3
330 O$=SEG("FAST  MEDIUMSLOW  ",6*(I-1)+1,6)
340 PRINT USING "8A13D18D":C$,C2(I),C1(I)
350 NEXT I
360 PRINT "JTOTAL KILLS = ";SUM(C2);"    TOTAL HITS = ";SUM(C1)
370 PRINT USING """JJAVE. DISTANCE FOR KILLS = ""2D.2D":K9
380 PRINT "JLAUNCHES = ";L9+L7;"_SPLASHES = ";L8;"_INFLITES = ";L7
390 PRINT "_R= ";R1 MAX 0
400 INPUT O$
410 DIM R(U,6),F(3),F4(3),F5(3),F6(3),F7(6),H(SUM(C1) MAX 1)
420 READ F,F4,F5,F6,F7
430 DATA 2,5,12,9,15,28,5,3,1,6,45,44,44,1,2,4,5,10,20
440 N0=N/3
450 O=0
460 J=1
470 R=0
480 K4=U
490 W=0
500 Y=0
510 REM........ ..W=look-up table for targets by track no
520 REM.  .. ... .O(I,1)=Entry U, O(I,2)=Optimal U for launch
530 REM.  . ......O(I,3)=U of player's killing launch
540 REM.  .. .....O(I,4)=# of inflight launches, O(I,5)=# of splashes
550 REM.  . ......H=updates on which hit(s) occurred
560 FOR I1=1 TO 3
570 FOR I=N0*(I1-1)+1 TO N0*I1
580 W(A8(I))=I
590 IF A5(I)<2000 THEN 620
600 O(I,1)=A5(I)-2000
610 GO TO 650
620 O(I,1)=A5(I)-1000
630 H(J)=O(I,1)+F4(I1)
640 J=J+1
650 O(I,2)=O(I,1)+F(I1)
660 K4=K4 MIN O(I,2)
670 NEXT I
680 NEXT I1
690 REM.. . .....Get launch info from L$:T1=Update..T2=Track No.
700 REM... ......Find splashes and inflite launches
710 FOR I=1 TO L/6
720 X$=SEG(L$,6*I-5,3)
730 T1=VAL(X$)-100
740 X$=SEG(L$,6*I-2,3)
750 T2=VAL(X$)
760 IF T2>699 THEN 870
770 X=T2-600
780 IF T1=>O(W(X),2) THEN 850
790 REM..........A splash, so engaged
800 O(W(X),5)=O(W(X),5)+1
810 FOR J=T1 TO T1+3
820 R(J,2)=R(J,2)+1
830 NEXT J
840 GO TO 890
```

```
850 O(W(X),3)=T1
860 GO TO 890
870 X=T2-700
880 O(W(X),4)=O(W(X),4)+1
890 NEXT I
902 REM.. .... ..Print data by target
910 FOR I=1 TO 3
920 PRINT "L";T$;"_                ";
930 PRINT "ANG     TN       E      L*       L      LAG    IN     SP     O_"
940 FOR J=N0*(I-1)+1 TO I*N0
950 O6=O(J,3)-O(J,2) MAX 0
960 Y(I,1)=Y(I,1)+O(J,5)
970 Y(I,2)=Y(I,2)+O6
980 Y(I,3)=Y(I,3)+O6↑2
990 Y(I,4)=Y(I,4)+O(J,4)
1020 A$=SEG("FMS",I,1) .
1010 C$=SEG("HK",O(J,3) MIN 2,1)
1020 PRINT USING 1040:J,A$,A1(J),A8(J),O(J,1),O(J,2),O(J,3)
1030 PRINT USING 1050:O(J,3)-O(J,2),O(J,4),C(J,5),C$
1042 IMAGE 2D4X1A4X3D4X2D4X3D4X3D4X3D4XS
1050 IMAGE 3D4X2D4X2D4X1A
1062 NEXT J
1070 INPUT O$
1080 NEXT I
1092 PRINT "_IHHHHMEAN LAG      SD LAG        N        IN        SP"
1100 FOR I=1 TO 3
1110 C$=SEG("FASTMED SLOW",4*(I-1)+1,4)
1120 PRINT C$;" TARGETS    ",
1130 PRINT USING "2D.2D7XS":Y(I,2)/C2(I)
1142 PRINT USING "2D.2D7XS" SQR((Y(I,3)-Y(I,2)↑2/C2(I))/C2(I))
1150 PRINT USING "2D7X2D7X2D":C2(I),Y(I,4),Y(I,1)
1160 NEXT I
1170 X=Y(1,2)+Y(2,2)+Y(3,2)
1180 S=Y(1,3)+Y(2,3)+Y(3,3)
1190 PRINT USING """_ALL  TARGETS    ""2D.2D7XS":X/SUM(C2)
1200 PRINT USING "2D.2D7XS":SQR((S-X↑2/SUM(C2))/SUM(C2))
1210 PRINT USING "2D7X2DS":SUM(C2),Y(1,4)+Y(2,4)+Y(3,4)
1220 PRINT USING "7X2D":Y(1,1)+Y(2,1)+Y(3,1)

1230 INPUT O$
1240 REM..........Aanlysis by update...R(J,1)=Active
1250 REM..........R(J,2)=Engaged...R(J,3)=Kills.. R(J,4)=Hits
1260 REM .........R(J,5)=Unengaged.. R(J,6)=Missed opps.
1270 FOR I1=1 TO 3
1280 FOR I=N0*(I1-1)+1 TO N0*I1
1290 K5=O(I,3)-1
1300 IF O(I,3)=0 THEN 1550
1310 REM  ........Process the kill
1320 X1=F6(I1)-F5(I1)*(O(I,3)-O(I,1))
1330 X2=5
1340 K=O(I,3)-1
1350 IF X1<=X2 THEN 1410
1360 X1=X1-F5(I1)
1370 X2=X2+5
1380 K=K+1
1390 GO TO 1350
1400 REM.........target is active
1410 FOR J=O(I,1) TO K
1420 R(J,1)=R(J,1)+1
1430 NEXT J
1442 FOR J=K+1 TO U
1450 R(J,3)=R(J,3)+1
1460 NEXT J
1470 REM.........target is engaged
1480 IF K+1=O(I,3) THEN 1520
1490 FOR J=O(I,3) TO K
1500 R(J,2)=R(J,2)+1
1510 NEXT J
1520 IF O(I,3)=O(I,2) THEN 1690
1530 GO TO 1620
1540 REM..........Process the hit
1550 FOR J=O(I,1) TO O(I,1)+F4(I1)-1
1560 R(J,1)=R(J,1)+1
1570 NEXT J
1580 FOR J=O(I,1)+F4(I1) TO U
1590 R(J,4)=R(J,4)+1
1600 NEXT J
```

```
1610 K5=O(I,1)+F4(I1)-1
1620 J1=1
1630 REM.........Unengaged targets and missed opps.
1640 FOR J=O(I,2) TO K5
1650 R(J,6)=R(J,6)+J1
1660 R(J,5)=R(J,5)+1
1670 J1=J1+1
1680 NEXT J
1690 NEXT I
1700 NEXT I1
1710 PRINT "L",T$;"_  U   ACT  ENG   K    H  REM   UT    MO_"
1720 M=0
1730 U1=U-(R(U-1,3)+R(U-1,4)=N)
1740 FOR I=1 TO U1
1750 R5=N-R(I,1)-R(I,3)-R(I,4)
1760 PRINT USING 1770:I,R(I,1),R(I,2),R(I,3),R(I,4),R5,R(I,5),R(I,6)
1770 IMAGE 3D3X2D3X2D3X2D3X2D3X2D3X2D3X3D
1780 M=M MAX R(I,6)
1790 NEXT I
1800 INPUT O$
1810 REM.........Make the graph...axes,ticks, and values
1820 PAGE
1832 MOVE 10,10
1842 DRAW 110,10
1850 MOVE 10,10
1860 DRAW 10,100
1870 X1=100/U1
1880 X2=85/M
1890 FOR I=1 TO U1
1900 MOVE I*X1+10,10
1910 RDRAW 0,-2
1920 IF I/5<>INT(I/5) THEN 1940
1930 PRINT USING """HJ""2D":I
1940 NEXT I
1950 FOR J=1 TO 6
1960 IF INT(M/15) MAX 1<F7(J) THEN 1980
1970 NEXT J
1980 FOR I=0 TO M STEP F7(J-1)
1990 MOVE 10,I*X2+15
2000 RDRAW -2,0
2010 IF I/(5*F7(J-1))<>INT(I/(5*F7(J-1))) THEN 2040
2020 RMOVE 0,-1
2032 PRINT USING """HHH""3D":I
2040 NEXT I
2252 MOVE 0,70
2262 PRINT "P_E_R_F_O_R_M_A_N_C_E";
2272 MOVE 10,0
2282 PRINT T$;"I            UPDATE";
2092 MOVE K4*X1+9.5,11
2102 PRINT "↑↑"
2110 IF SUM(C1)=0 THEN 2170
2120 FOR I=1 TO SUM(C1)
2130 MOVE H(I)*X1+9.5,11
2140 PRINT "*";
2150 NEXT I
2160 REM.........Plot unengaged targets and missed opportunities
2172 MOVE X1+9,R(1,6)*X2+15
2180 FOR I=2 TO U1
2190 DRAW I*X1+9,R(I,6)*X2+15
2200 NEXT I
2210 FOR I=1 TO U1
2220 MOVE I*X1+9,R(I,5)*X2+14
2230 PRINT "+";
2240 NEXT I
2250 END
```

APPENDIX D

DATA ANALYSIS: PROGRAM VARIABLES

VARIABLE NAME	DEFINITION	TYPE
A$	Target speed designator(F, M, or S)	String
A1	Target bearing(degrees)	Array(N)
A5	Target entry time: plus 1000(hit) or 2000(killed)	Array(N)
A8	Target track number(TN)	Array(N)
C$	Outcome designator(hit or kill)	String
C1	No. of hits (fast, medium, slow)	Array(3)
C2	No. of kills (fast, medium, slow)	Array(3)
D	Code for tempo of operations	Simple
F	No. of updates until optimal launch	Array(3)
F$	Input for file to be analyzed	String
F4	No. of updates until hit occurs	Array(3)
F5	Target speeds	Array(3)
F6	Range at entry time	Array(3)
F7	Scale for ordinate in MO graph	Array(6)
H	Updates on which hits occurred	Array
I	Index in for-next loop	Simple
I1	Index in for-next loop	Simple
J	Index in for-next loop	Simple
J1	Counter for missed opportunities	Simple
K	Update at which kill occurs	Simple
K4	Update for first launch opportunity	Simple
K5	Last update prior to a hit	Simple
K9	Average distance for kills	Simple
L	Length of L$	Simple
L$	Player's launch history	String
L7	No. of inflight launches	Simple
L8	No. of splashes	Simple
L9	No. of good launches	Simple
M	Maximum value of MO by update	Simple
N	Total no. of targets	Simple

VARIABLE NAME	DEFINITION	TYPE
NO	No. of targets of each speed	Simple
Q	Table of target and launch information	Array(N,5)
Q$	Text for game parameters	String
Q6	Lag score	Simple
R	Table of target status by update	Array(U,6)
R1	Skill rating	Simple
R5	No. of targets remaining	Simple
S	Sum of squares for lags	Simple
S$	Player I. D.	String
T$	File number designator	String
T1	Code for update extracted from L$	Simple
T2	Code for track number extracted from L$	Simple
U1	Last update of game	Simple
W	Table for track number lookup	Array(99)
X	Sum of lags	Simple
X$	Launch information extracted from L$	String
X1	Temporary storage for kill computation; Unit for abscissa in MO graph	Simple
X2	Temporary storage for kill computation; Unit for ordinate in MO graph	Simple
Y	Summary table of lags, inflight launches, and splashes by target speed	Array(3,4)

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